PB-217 644

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Las Vegas, Nevada

1969

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From the Proceedings of a Symposium
BIOLOGICAL EFFECTS AND HEALTH IMPLICATIONS
OF MICROWAVE RADIATION

Richmond, Virginia, September 17-19, 1969

Sponsored by
MEDICAL COLLEGE OF VIRGINIA

With the Support of
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EFFECTS OF MICROWAVES ON OPTICAL ACTIVITY

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INTRODUCTION

The effects of microwave irradiation on optical activity are under investigation at the Southeastern Radiological Health Laboratory with the overall objective of developing a chemical dosimeter based on changing the optical activity of a compound with microwave irradiation. The initial phase of this study was to determine if microwave irradiation would in fact produce a change in the optical activity of a compound. Van Everdingen (1) showed that starch and glycogen solutions can be altered by microwave irradiation to produce complete optical inactivity in both systems. Preliminary data from this SERHL study indicate the presence of specific optical rotation changes as a result of microwave exposure, the optical activity being reduced in proportion to the amount of microwave exposure.

A number of optically active compounds have been evaluated. It was found that the optical rotation of sucrose in a mixture of Triton N-101[2] and water could be altered. Also, the optical activity of sucrose in a mixture of glycerin and polyvinylpyrrolidone could be altered. In both cases the optical activity of sucrose was reduced in proportion to the amount of microwave irradiation. The effect of heat was compared to that of microwave exposure on each mixture and experimental data are presented.

EXPERIMENTAL

All microwave exposures were done with a microwave oven with a frequency of 2450±50 MHz. The magnetron was pulsed at 60 Hz with pulse duration on the order of 5 msec. The oven was allowed to stabilize (or "warm up") thirty minutes prior to sample irradiation.

Samples (liquids in 50-ml pyrex volumetric flasks, solids in plastic dishes) were placed approximately in the center of the oven for each irradiation. Prior experiments determined that the central area of the oven received maximum irradiation. Solid samples were given continuous microwave irradiation, whereas liquid samples, which absorbed microwave energy more readily, were subjected to irradiation for one to one and one-half minute intervals or less to avoid excessive heat buildup. Samples were allowed to cool to room temperature between each exposure. Approximately 50 optically active compounds including several proteins, sugars, steroids, amino acids, hormones, enzymes and others were irradiated in their natural state for prolonged periods of time. Some were irradiated for as long as one hour. The minimum exposure time was 15 minutes. No changes in the optical activity of these compounds were observed.

These compounds were then solubilized prior to irradiation. Compounds that were soluble in water and/or glycerin were dissolved, Triton N-101 being added to the water solutions to adjust the viscosity. Triton N-101 is one of the alkylphenoxy polyethoxy ethanol series of surface-active agents.

Van Everdingen (1) pointed out the importance of the viscosity term in Debye's equation for relaxation times of polar particles in a viscous medium, reasoning that at a certain combination of viscosity and frequency, maximal energy absorption would occur.

The optical activity of the compounds dissolved in glycerine remained unchanged after prolonged irradiations, however, sucrose in a Triton N-101-water mixture exhibited a change in optical activity. The ratios of the three components (sucrose, water and Triton N-101) were then varied to determine the optimum proportions that would allow a maximum change in optical activity in relation to microwave exposure. A mixture consisting of 20 grams sucrose, 20 grams water, and 60 grams Triton N-101 resulted in a maximum change.

Temperature determinations were made immedi-

[1] Now located at Southwestern Radiological Health Laboratory. P.O. Box 15027, Las Vegas, Nevada, 89114.

[2] Trade mark, Rohm and Haas Co.

ately after removal of the sample from the oven. Temperatures of the samples after a one-minute exposure ranged from 95° to 107 °C using a thermistor for temperature determinations.

To compare the effect of heat versus microwaves, samples identical to those irradiated in the oven were heated in a mineral oil bath at 125 °C for one-minute intervals which allowed the samples to reach approximately the same temperatures as reached during microwave exposure.

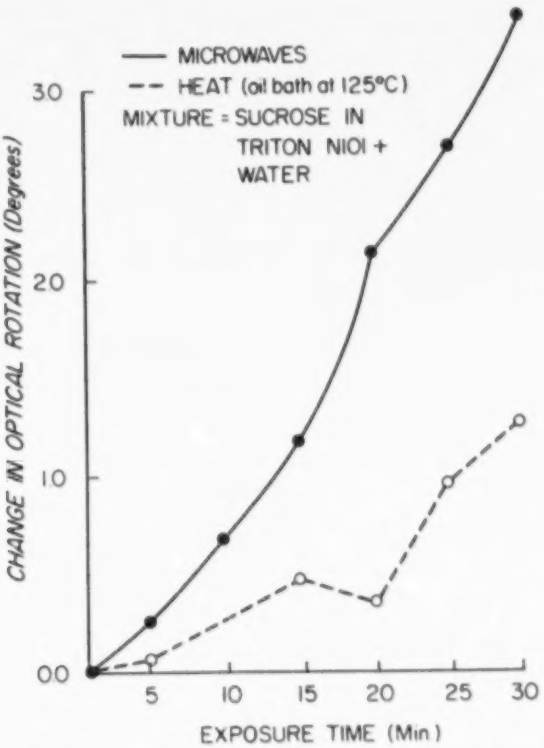

Figure 1. Changes in optical rotation as a function of heat and microwave exposure.

Figure 1 shows a comparison of sucrose-water-Triton N-101 samples heated in an oil bath versus samples exposed to microwaves. Both heat and microwaves altered the optical activity of sucrose, however, microwaves have a more pronounced effect.

Attempts to reproduce results with several lots of Triton N-101 or with similar detergents were unsuccessful. It was then decided that some impurity in the Triton N-101 was responsible for the

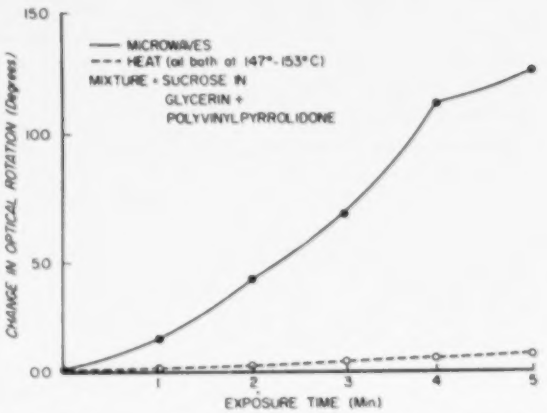

Figure 2. Effects of heat and microwave exposure of the sucrose in glycerin and polyvinylpyrrolidone mixture.

change in optical activity. Other viscosity modifiers were tested.

Replacement of the Triton N-101 and water with polyvinylpyrrolidone and glycerin resulted in changes in optical rotation upon microwave exposure. Pronounced changes were noted after a 30-second exposure period. The mixture consisted of 20 grams sucrose and 1 gram polyvinylpyrrolidone per 100 ml of glycerin. The pH of the mixture prior to microwave exposure was 5.4 and dropped to 4.3 after 5 minutes of irradiation. Temperatures of the samples upon removal from the oven ranged from 142–144 °C.

Samples of the same mixture were also heated in an oil bath to temperatures of 147–153 °C. Figure 2

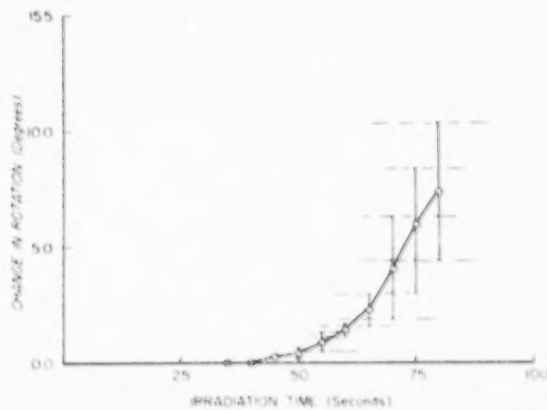

Figure 3. Reproducibility of optical rotation changes induced by microwave exposure of the sucrose in glycerin and polyvinylpyrrolidone mixture.

illustrates results of the heat versus microwave exposure on the glycerin-polyvinylpyrrolidone-sucrose mixture. Heat had very little effect on the optical activity, whereas, microwaves had a very pronounced effect. It may also be noted that the effect of microwaves on the sucrose-polyvinylpyrrolidone-glycerin was much more pronounced than that of the sucrose-detergent-water mixture.

Reproducibility of the experiments was difficult to achieve due to the variables associated with the procedure. Everything was kept as constant as possible, including the load, placement of samples in the oven, sample size and geometry. However, the power output of the oven varied appreciably.

To determine the variation of the power output, one-liter containers of water were irradiated for two-minute intervals. The variation in temperature rise of the water was used to determine the variation in power output. Overall, the power output decreased with intermittent oven usage, however, the power output would increase slightly during a period of continuous use.

A series of replicate samples of sucrose-polyvinylpyrrolidone-glycerin was irradiated for intervals ranging from 35 to 80 seconds. Ten samples were irradiated for each time interval. Results of this experiment are shown in Fig. 3. The averages of the ten samples for each time interval are plotted and show a decrease in optical rotation with increased microwave exposure. The ranges of the data are indicated by the vertical lines showing variations obtained.

The total energy absorbed from the microwave radiation field in the microwave oven by the samples used in these experiments is not known, therefore, the functional relationship between changes in optical activity and absorbed microwave energy has not been determined. A microwave radiation field of known power density will be used in future experiments to study this relationship.

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1. W. A. C. Van Everdingen: Rev. Helge Sci. Med. *17*, 261 (1946).

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